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FRAGMENTATION OF THE LAND-WATER MARGIN WITHIN THE NORTHERN AND CENTRAL INDIAN RIVER LAGOON WATERSHED

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ABSTRACT

Salt marshes, mangrove swamps, estuarine shrubs, tidal flats and estuarine waters dominate the natural communities of the coastal zone comprising approximately 35% of the northern and central Indian River Lagoon watershed. Fragmentation of natural communities within the Indian River Lagoon ecosystem has compartmentalized ecological and physiographic functions that once operated at a larger scale. Natural community and land cover GIS databases were used to identify shoreline areas within the Indian River Lagoon ecosystem that, because of their context within the landscape, have become highly fragmented. Estuarine natural communities occupied about 700 km of the 1,700 km land-water margin. Almost 40% of these salt marsh and swamp communities existed in isolated areas, 10 to 12,000 ha in size. Large natural area fragments, with high natural community heterogeneity, contiguous with the estuary were identified as areas for land acquisition. Maintaining the diversity of ecological and physiographical functions within the Indian River Lagoon ecosystem is imperative for it's long-term conservation. Land management and planning agencies must incorporate both the content and context of natural area units within the Indian River Lagoon to properly conserve the integrity of the ecosystem.

A regional biodiversity conservation strategy for the Indian River Lagoon (IRL) system should be approached using ecosystem level conservation methods such as: (1) land acquisition and establishment of reserve networks, (2) conservation and maintenance of all natural areas on both public and private land, regardless of the degree of fragmentation or degradation (3) restoration or rehabilitation of disturbed habitat using existing natural communities within the landscape as building blocks.

Conservation efforts in the IRL poses a particular challenge because they must include interactions between both terrestrial and estuarine communities (Livingston, 1990; Risser, 1990). Estuarine natural communities have very high levels of productivity that add complexity to both the aquatic and terrestrial components of the ecosystem (Montague and Wiegert, 1990; Odum and McIvor, 1990; Gilmore and Snedaker, 1993). The salt marshes, mangrove swamps, estuarine shrubs, and tidal flats of the IRL support a large percent of the listed species found within central Florida's east coast (Table 1), including all of the listed invertebrates and fish for the region. Limited data are available to quantify the significance of the ecological processes (e.g., nutrient cycling, landscape hydrography, and sediment stabilization) associated with these communities. Quantitative data on the composition and spatial distribution of the natural communities within the IRL watershed is needed to incorporate both estuarine and terrestrial functions into a regional biological conservation strategy.

Characterization of the land-water margin within the IRL watershed can be used to identify threats affecting these physical and biogeographical systems within the estuary. Urban development and landscape alteration have changed natural processes which once occurred on a larger scale throughout the estuary (Risser, 1990). The natural drainage patterns of upland communities into the estuarine system have been changed by mosquito impoundments, ditching, and urban development. Rey and Kain (1991) reported that 129 mosquito impoundments have

Table 1. The number of listed species, grouped by taxa, associated with the estuarine natural communities of Brevard Co. Listed species include those that are potentially rare, threatened or endangered by federal or state agencies of Florida, Florida Natural Areas Inventory (FNAI), and Florida Committee on Rare and Endangered Plants and Animals (FCREPA) (Larson, 1992).

	Number of listed species				
Taxa	Salt marsh	Estuarine shrubs	Salt marsh open water	Tidal flats	Mangrove swamp
Plants	11	11	1	1	13
Inverts	2	2	2	0	2
Fish	5	5	5	0	5
Reptiles	4	4	4	0	4
Birds	32	32	39	28	22
Mammals	3	3	4	1	4
Total	57	57	55	30	50

impacted 16,356 ha of estuarine communities in the IRL. Urban and agricultural land uses have altered 54% of the northern and central IRL watershed (Larson, 1992). Land use practices have changed nutrient cycles, increased the amount of fresh water entering the estuary, increased exotic plant and animal invasion, and suppressed naturally occurring fires (Schmalzer, 1995). Fragmentation of natural areas, especially by roads, has restricted animal and plant dispersal and increased animal mortality (Oxley et al., 1974; Mader, 1984; Dreschel et al., 1990; Simberloff, 1993). Urban land uses have increased the physical threats of storm surges and high winds on adjacent natural areas.

These aspects of landscape change present tremendous ecological pressures (Usher, 1987). In this paper, I describe the spatial fragmentation of the estuarine communities in their landscape context. A characterization of the land-water margin and quantification of natural area fragments are presented as a large scale approach to identifying areas important to the biodiversity of the IRL system.

Methods

Natural community and land cover Geographic Information Systems (GIS) databases for the northern and central IRL watershed, from Ponce de Leon Inlet south to the Indian River/St. Lucie County line, were analyzed to characterize the land-water margin and identify the spatial fragmentation of the natural areas within the watershed. The land-water margin was defined by the land cover class found adjacent to the open surface water of the estuary. Land-water margins were classified into two natural community classes (mangrove/salt marsh and other natural communities) and four other classes (disturbed vegetation/exotics, spoil/sand, urban/developed, and canals/waterways) that represent varying degrees of human impact to the landscape (modified from FLUCCS, 1985; FNAI and FDNR, 1990). Salt marshes included estuarine shrubs, open water within the salt marsh, and tidal flats. Estuarine shrubs and tidal flats were grouped with salt marsh because they represented a very small proportion of the total area analyzed. Open water within salt marshes was included as salt marsh because its occurrence is seasonal or dependent on mosquito impoundment management. Disturbed vegetation and exotics included monotypic stands of wax myrtle, successional mixed shrub communities, Brazilian pepper, and Australian pine.

Land-water margins that consisted of mangrove swamp, salt marsh, or other natural communities were used to generate natural area fragments. The natural area fragments consisted of natural communities contiguous with the estuarine waters of the northern and central IRL watershed or its tributaries. The fragments were defined by biogeographical barriers that restricted hydrological and other physical processes and faunal or floral dispersal (i.e., causeways, roads, railways, etc.). Mosquito impoundment dikes were classified as spoil and were not considered a barrier; however, they do alter estuarine hydrology, nutrient flow, and restrict some faunal movement. Natural area fragments were connected only by open surface water of the estuary. GIS overlay analyses were performed to determine the quantity and heterogeneity of the natural communities within each fragment. Comparisons of fragments were based on geographical distribution, size, and natural community composition.

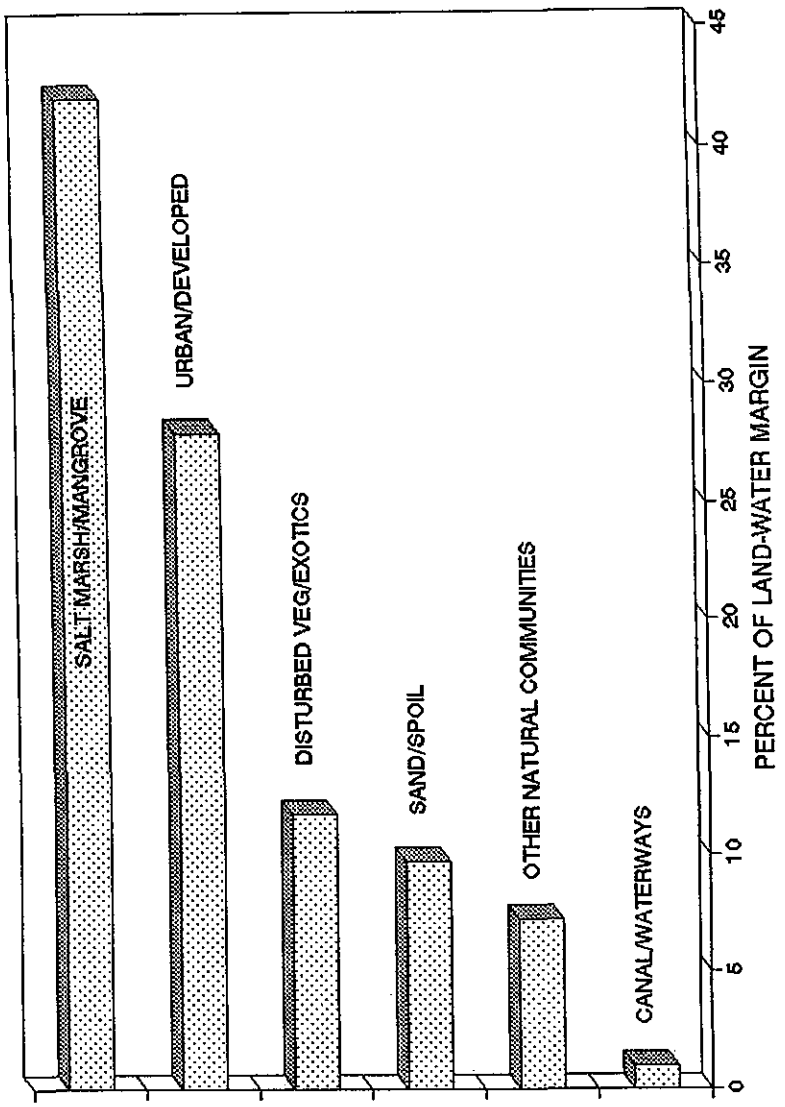

Figure 1. The linear proportion of general land cover classes found along the land-water margin of the northern and central Indian River Lagoon watershed.

Results

Mangrove swamps and salt marshes made up about 700 km of the 1,700 km (42%) of land-water margin analyzed (Fig. 1). Both natural and human impacted shorelines (e.g., those diked for mosquito control) with complex ecological and geophysical functions and high species utilization (Table 1) were represented. Other natural communities comprised about 7% of the land-water margin (Fig. 1). The most extensive portion of estuarine communities existed along the shorelines of the northern IRL watershed (Fig. 2), throughout Mosquito Lagoon, the northern portion of the Indian River, and within Kennedy Space Center (KSC)/

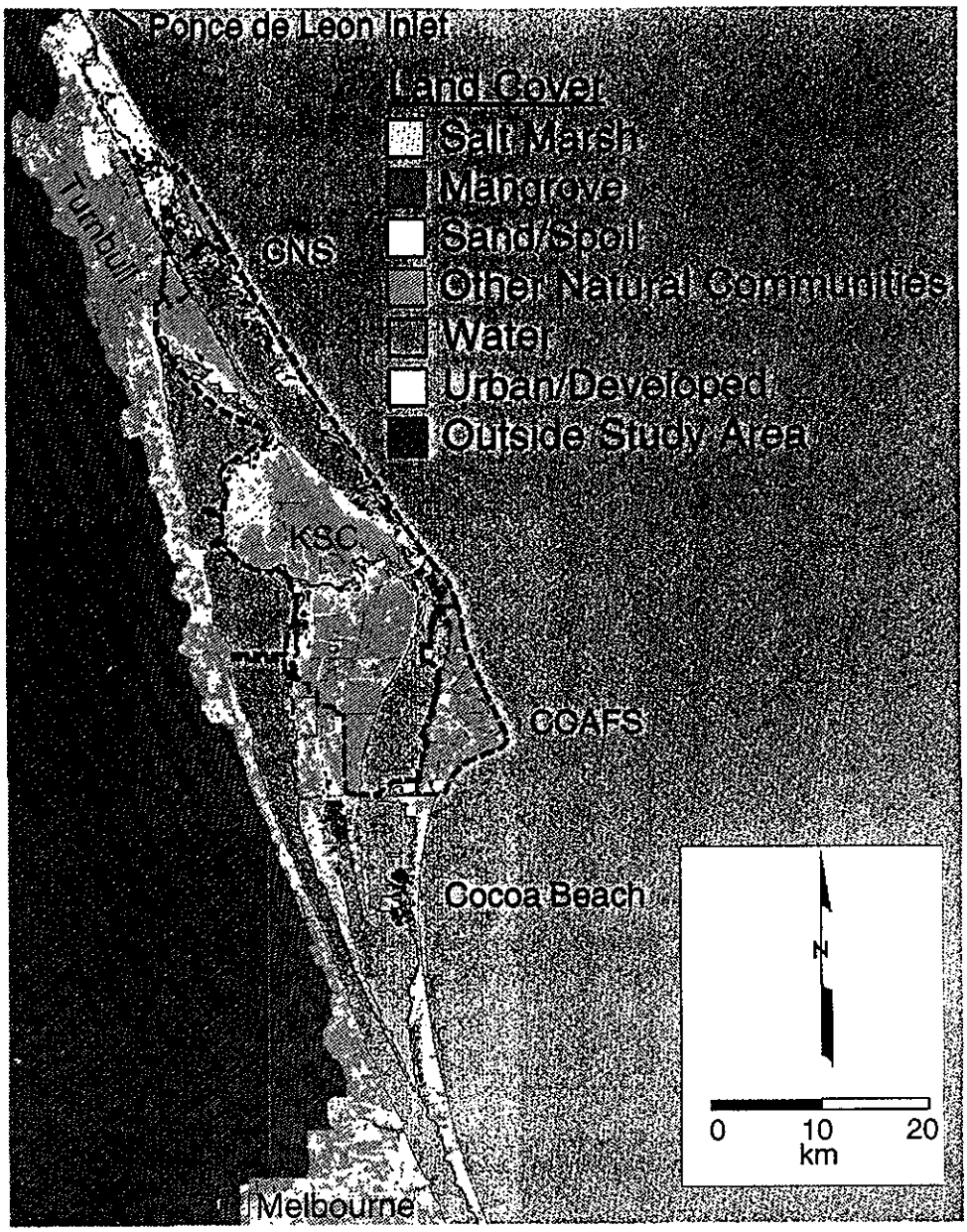

Figure 2. The spatial distribution of estuarine natural communities in the northern Indian River Lagoon watershed.

Merritt Island National Wildlife Refuge (MINWR), Canaveral National Seashore (CNS) and Cape Canaveral Air Force Station (CCAFS). Although these land-water margins are estuarine communities, >50% have been impacted by impoundment or created as spoil islands.

Disturbed vegetation, exotics, sand, and spoil land cover types consisted of

both natural and artificial margins within the IRL. Sand and spoil margins, mostly man-made spoil islands and mosquito impoundment dikes, covered 163 km of shoreline. Nearly 200 km of the land-water margin was dominated by exotic Brazilian pepper, Australian pine, or other types of shrub vegetation indicative of disturbance.

Urban and developed land made up about 30% or 470 km of land-water margin of the IRL watershed. Shorelines altered by anthropogenic disturbances were the second most common occurrence along the land-water margin (Fig. 1). Single family residents and commercial businesses represented the largest urban land cover types that intermittently border the IRL from Titusville south to Vero Beach (Figs. 2, 3). Intense coastal development has occurred in association with the cities of Titusville, Cocoa, Cocoa Beach, Melbourne, Sebastian, and Vero Beach.

The IRL watershed consisted of 22 natural area fragments (Fig. 4) ranging in size from 10 to 10,223 ha (Fig. 5), not including the open water of the estuary or its major tributaries. Causeways, roads, and railways were the most common biogeographical barriers that characterized the edges of the natural area fragments. Ten of the natural area fragments were <250 ha and three fragments ranged from 250–1,000 ha. Approximately half of the small fragments (i.e., <1,000 ha) were greater than 70% estuarine communities. Three of these small fragments were part of KSC/MINWR and CCAFS (fragments 4, 8, and 9; Fig. 4). The remaining small fragments occurred near Ponce Inlet (fragment 1) and between Cocoa and Vero Beach, near urban areas (fragments 12–18, 21, 22; Fig. 4). Fewer natural community types were found on the small fragments compared to the larger ones (i.e., >1,000 ha) (Fig. 5). Six natural area fragments were between 1,000-2,500 ha. Four fragments occurred as a part of KSC/MINWR, CNS and CCAFS and adjacent natural areas (fragments 5, 7, 10, and 11), and two in the Sebastian and Wabasso area (fragment 19 and 20; Fig. 4). Two fragments located on the Indian River and the Banana River of Merritt Island (fragments 10 and 11; Fig. 4), adjacent to the south boundary of KSC/MINWR and CCAFS, have a very high natural community heterogeneity and were represented by nearly all the natural community types (N = 32) found within the IRL watershed (Fig. 5). The largest three natural area fragments (i.e., >2,500 ha) occurred on public lands and adjacent natural areas. The largest fragment (fragment 2; Fig. 4) was a part of CNS in Mosquito Lagoon (10,223 ha). The other two large fragments (fragment 3 and 6; Fig. 4) occurred as a part of KSC/MINWR in the Indian River and privately owned natural areas in Turnbull/Scottsmoor and Merritt Island. These large fragments included nearly all of the natural community types found in the watershed. Sixty-two percent of the salt marsh and mangrove swamps, both natural and impounded, occurred on KSC/MINWR, CNS, and CCAFS (Table 2, Fig. 3).

Discussion

Mangrove swamps and salt marshes, which include estuarine shrubs, tidal flats and open water within the salt marsh, are natural communities that are considered to be of very high value to the conservation of biodiversity in the IRL (Breininger et al., 1994; Larson, 1992). The importance of these habitats for plants and animals that are listed as threatened or endangered or recognized as species of concern (Table 1; Swain et al., 1993) is evident. The functional role of these estuarine communities within the ecosystem is less obvious. There are little scientific data to quantify the functional changes in the IRL ecosystem related to the loss or alteration of estuarine communities. Most scientists agree that loss of estuarine habitat has contributed to changes in nutrient cycles, sedimentation rates, and

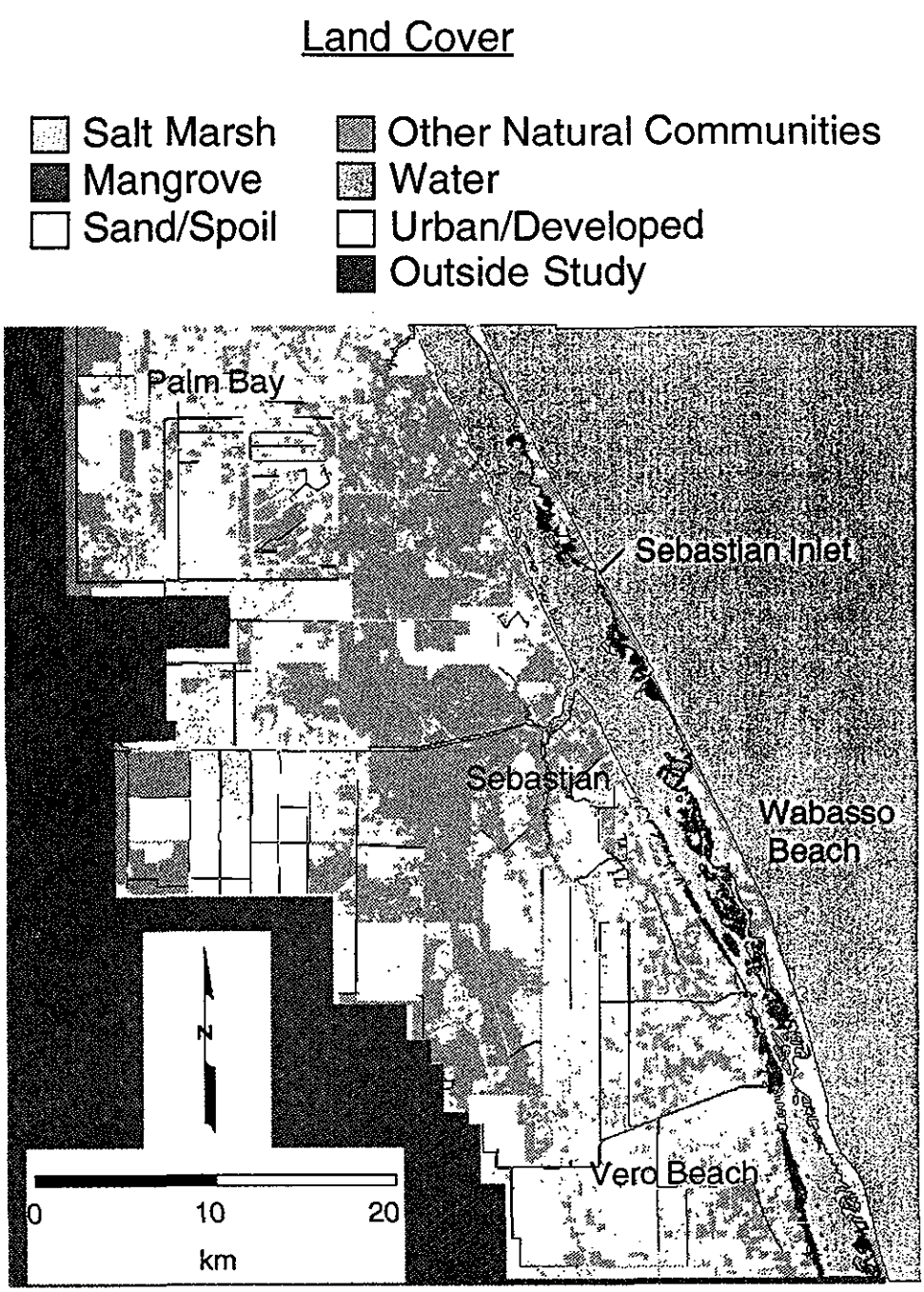

Figure 3. The spatial distribution of estuarine natural communities in the central Indian River Lagoon watershed.

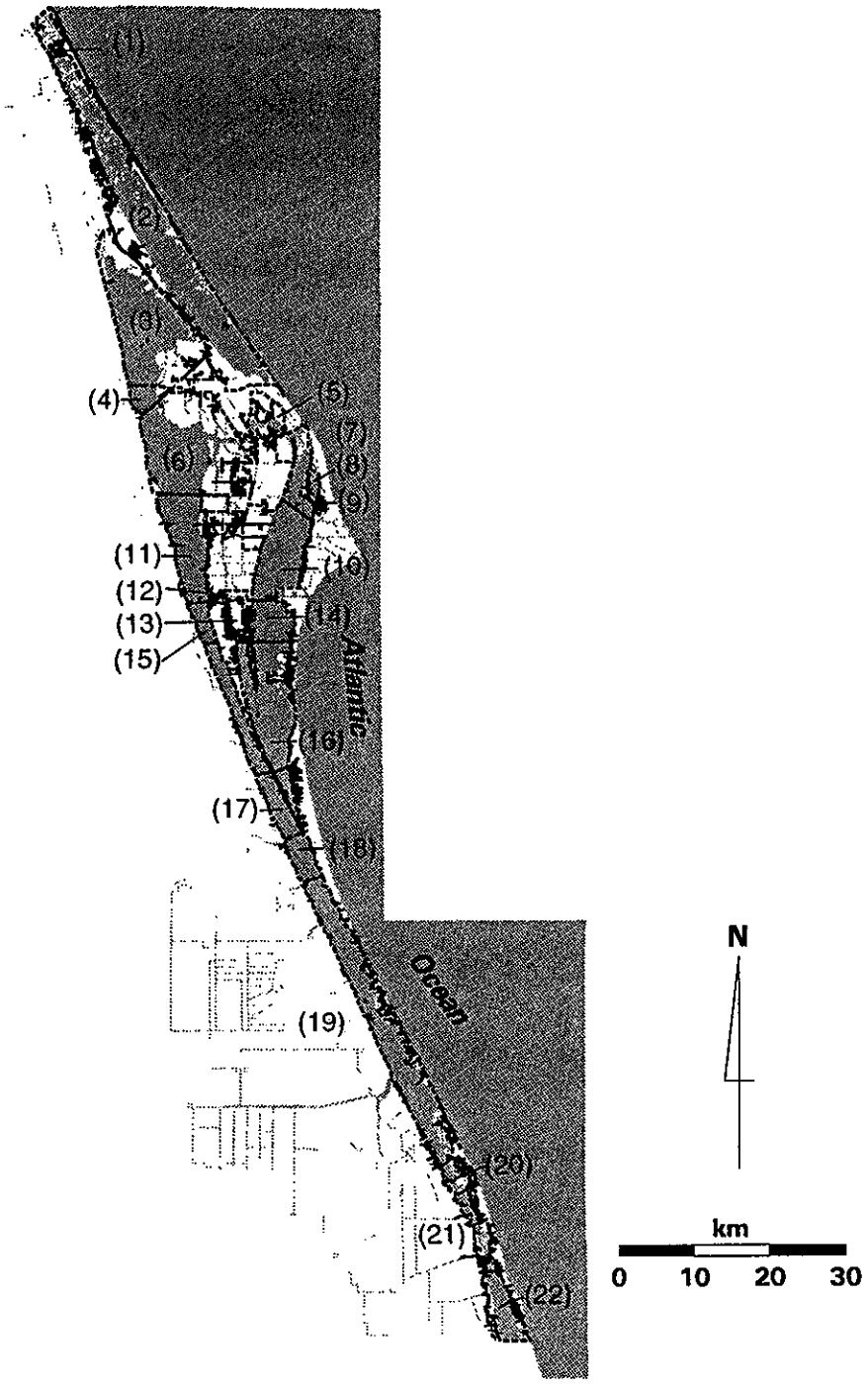

Figure 4. The spatial distribution of the natural area fragments of the northern and central Indian River Lagoon watershed. Dashed lines indicate natural area fragments boundaries. Values in parenthesis represent natural area fragment numbers that correspond to Figure 5.

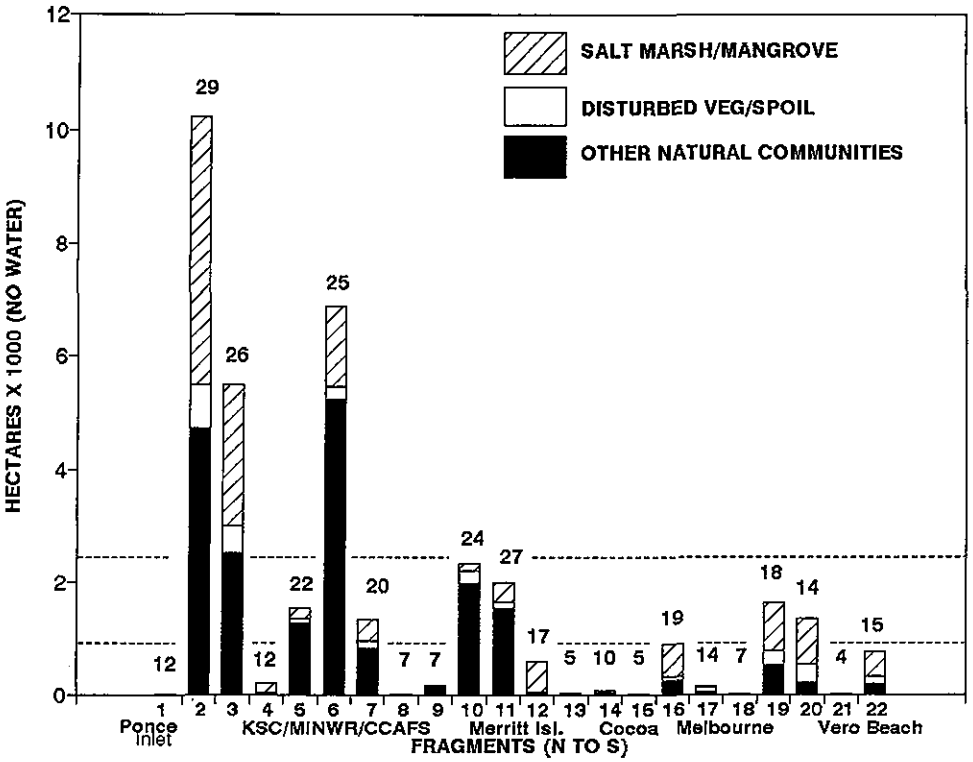

Figure 5. The size and relative composition of natural area fragments adjacent to the surface waters and tributaries of the northern and central Indian River Lagoon watershed. Open waters of the estuary and its major tributaries are not included in the areas. Values above bars indicate the number of natural community types found within that fragment. Salt marsh included estuarine shrubs, open water within the salt marsh, and tidal flats. Disturbed vegetation included exotics, wax myrtle and mixed shrub communities.

ecosystem hydrology. While research continues, conservation efforts must focus on preserving ecosystem integrity (i.e., functions as well as biological components).

The majority of estuarine communities that remain in the IRL are limited to the northern portion of the watershed, from Ponce Inlet to Merritt Island. The

Table 2. The amount of estuarine natural communities found within the northern and central Indian River Lagoon watershed and the proportion of these communities found within the public lands of Kennedy Space Center (KSC)/Merritt Island National Wildlife Refuge (MINWR), Canaveral National Seashore (CNS), and Cape Canaveral Air Force Station (CCAFS).

Natural community	Area (ha)		Percent
	Total	Protected	
Salt marsh	7,830	4,895	62.52
Openwater in salt marsh	2,776	1,995	71.87
Tidal flat	107	38	35.51
Estuarine shrubs	600	253	42.17
Mangrove	3,951	1,284	32.50
Total	11,313	7,181	63.48

lack of cities and the extent of public land in this region has restricted development. Large, privately owned natural areas with a high diversity of estuarine communities and other natural communities should be targets for land acquisition. These large natural areas have a high value to conservation and biological diversity because they provide: extensive habitat for both narrow and wide ranging species (Harris and Eisenberg, 1989), connections between multiple habitat types (Noss and Harris, 1986), and areas for floral and faunal movement triggered by changing environmental conditions (Peters and Darling, 1985; Hunter et al., 1988; Weiss and Murphy, 1993). They are also important as biological and physical connections between the upland and the estuary (Fahrig and Merriam, 1985); areas for organisms to forage and mechanisms for nutrient recycling.

Major land acquisitions in the north Indian River, Turnbull and Scottsmoor areas, in both Brevard and Volusia Counties are underway (EELP, 1992). The Sykes Creek area on south Merritt Island has been heavily impacted by urban development, but many natural areas remain. The size (i.e., several fragments >1,000 ha), proximity to KSC/MINWR, natural community diversity and extent of upland estuarine margin have made these areas a priority for land acquisition.

Maintenance of biodiversity within any anthropogenic landscape requires both public and private land management (O'Connell and Noss, 1992). The natural area fragments, presented here, provide a geographical basis for management units in a biodiversity conservation strategy for the IRL system. The natural area fragments, excluding the natural area fragments found on KSC/MINWR, CNS and CCAFS, currently managed by national agencies, average about 1,500 ha, making them reasonable size management units. These management units incorporate the geography of the region, since the northern portion of the IRL system provides habitat for species whose range does not extend into the southern region and vice versa. As an example, the range of the federally threatened Atlantic salt marsh snake (*Nerodia clarkii taeniata*) is limited to Volusia, Brevard and Indian River counties (Fig. 1) (Kochman and Christman, 1992). Developing conservation strategies and reserve designs (both within and between management units at a landscape scale) that incorporate the negative influences of habitat fragmentation with known species and natural community distributions and abundances (Scott et al., 1993) have the greatest potential of conserving the unique functions of the IRL watershed (Margules et al., 1988; Hansson and Angelstam, 1991; Woinarski, 1992). Planners and permitting agencies need to restrict development that continues to divide the natural areas into smaller fragments. The spatial context of the landscape surrounding a project should be considered in the permitting process. Habitat restoration and rehabilitation should also be considered to restore ecosystem function and minimize the net loss of system diversity (Noss, 1991). Restoration efforts in the IRL watershed should target exotic and disturbed vegetation as well as degraded natural communities that have the greatest potential for success based on their function in the landscape (e.g., a restoration area may provide a connection between larger natural area fragments). This analysis of land-water margin could be used to locate potential areas for restoration. GIS and field analysis of specific shorelines, more detailed than presented here, should be done to identify restoration sites since some of these areas provide habitat for listed species. Sand and spoil areas provide habitat for wading birds (Smith and Breininger, 1995), shorebirds and particularly the diamondback terrapin (*Malaclemys terrapin*) (Seigel, 1993). Disturbed and exotic vegetation are used as rookeries and nesting substrate for wading birds, pelicans, cormorants and other estuarine bird species in certain locations (Sewell et al., 1995). Continued improvement of techniques for ecosystem restoration and monitoring within human-impacted areas are

essential for success in conserving biodiversity at both local and global scales (Cairns, 1986; Noss, 1991; Recher, 1993).

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